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(54) Title: ROTARY VACUUM PUMP

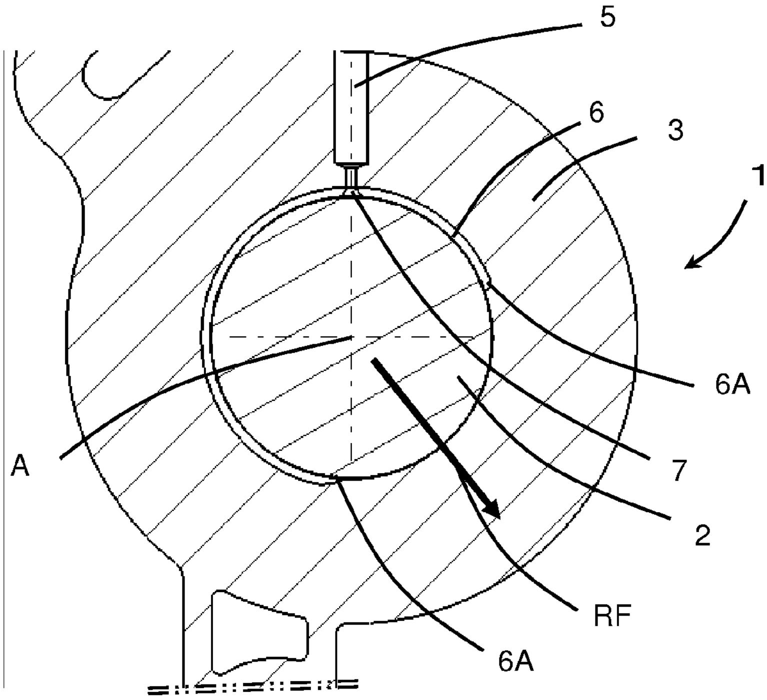

FIG. 1

(57) Abstract: A rotary vacuum pump, for instance a vane pump, has at least one circumferential groove (6) between facing side surfaces of the rotor (2) and of the rotor guide (3) for receiving a lubricating and sealing fluid. The circumferential groove (6) is a partial annular groove, which has an angular extension of less than 360° and has at least one interruption enabling creating a hydrodynamic fluid bearing in a region opposite a discharge region of the pump (1; 101; 121; 201), over the whole axial extension of the facing surfaces. A method of lubricating a rotary vacuum pump is also provided.

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ROTARY VACUUM PUMP

Technical field

The present invention relates to a rotary vacuum pump and to a method of lubricating such a pump.

Preferably, but not exclusively, the present invention is applied in the automotive field, in particular for intaking air from the brake booster.

Prior Art

Vacuum pumps commonly used in brake boosters of motor vehicles are rotary pumps having a rotor with one or more vanes which, during the rotation of the rotor, give rise to chambers with variable volume. The rotor is made to rotate about an axis, e.g. by the shaft of the vehicle engine, by means of a suitable drive joint, and is housed in a rotor seat or guide that, in most cases, is lubricated, typically with engine oil supplied through a supply channel. Lubrication is aimed at preventing wear of the pump and at creating a seal between the inside and the outside of the pump. Generally, one or more axial grooves are also provided on the rotor guide, in order to improve the transportation of the lubricant towards the pump inside in order to lubricate the components within the pump.

Air from outside the pump (typically at atmospheric pressure) can leak towards the inside of the pump (under negative pressure) through the clearance between the rotor and the guide. Such an air leak towards the inside of the pump increases the power absorbed by the pump and lowers its performance.

In order to reduce such a leak, it has already been proposed to provide an annular groove, filled with lubricant, between the rotor guide and the rotor. The groove may be formed on the rotor guide surface or on the rotor surface or may be defined by steps of such surfaces, and it extends over the whole circumference of the concerned surface(s). Examples of pumps with such an annular groove are disclosed in WO 2009/046810 and FR 2640699. The annular groove improves sealing by providing an oil barrier between the inside and the outside of the pump, thereby preventing air from entering again the pump through the rotor - rotor guide clearances. Yet, such an arrangement gives rise to a problem.

Pressures inside the pump chamber vary with time and are different in the different chambers. Such pressure differences generate forces that radially push the rotor against the guide. Such forces are balanced by the pressure originating in the hydrodynamic bearing provided by the oil between the rotor, which is rotating, and the guide. The provision of an annular groove extending over 360° reduces the area in which the rotor is in contact with the rotor guide and breaks the hydrodynamic bearing in the region of the annular guide and in adjacent areas, thereby reducing the balancing effect on the forces inside the pump. This causes a worsening of the wear with respect to the conventional configurations without annular groove, especially in the mutually contacting areas of the rotor and the guide.

The higher wear, during the pump operating life, produces greater guide-rotor clearances, which in turn cause:

- worsening of the sealing provided by the groove, with a consequent increase of the power absorbed by the pump and a lowering of the pump performance;
- increase in oil absorption by the pump.

It is the object of the invention to provide a vacuum pump and a method of lubricating same that obviate the drawbacks of the prior art.

Description of the invention

According to the invention, this is achieved in that the pump includes at least one partial annular groove (or circumferential groove), which has an angular extension of less than 360° and has at least one interruption arranged to enable creating a hydrodynamic fluid bearing in a region opposite a discharge region of the pump, over a whole axial extension of facing side surfaces of the rotor and the rotor guide.

Advantageously, the at least one circumferential groove has an extension ranging from 150° to 300° and preferably from 180° to 220°.

The at least one circumferential groove may be arranged orthogonally to the rotation axis of the rotor or it may be inclined with respect to said axis. The second solution improves axial lubrication.

The at least one circumferential groove may be formed in the side surface of the rotor or of the guide or it may be defined by steps of said side surfaces. In case of a groove formed in the surface of a vane rotor, the or each groove consists of at least one pair of arcs separated by an equal number of interruptions. In particu.ar, an arc and an interruption are provided for each discharge phase at each revolution of the pump rotor, the arcs and the interruptions being arranged so that, during the discharge phases, the interruptions between the arcs pass in the region opposite the discharge region.

In a second aspect of the invention, a method of lubricating a rotary vacuum pump comprises forming, between facing side surfaces of the rotor and of the rotor guide, at least one circumferential sealing barrier, which has an angular extension of less than 360°

and has at least one interruption arranged to enable creating a hydrodynamic fluid bearing in a region opposite the discharge region of the pump, over the whole axial extension of said side surfaces.

Brief Description of the Figures

Further features and advantages of the invention will become apparent from the following description of preferred embodiments, given by way of non limiting example with reference to the accompanying drawings, in which:

- Fig. 1 is a sectional view, orthogonal to the rotor axis, of a vacuum pump incorporating the invention, in a first embodiment in which the circumferential groove is formed on the rotor guide;
- Fig. 2 is an axial section of the pump shown in fig. 1;
- Fig. 3 is a schematic sectional view, orthogonal to the rotor axis and taken along a plane passing through line III - III in fig. 2,
- Figs. 4 and 5 are sectional views of the rotor guide, orthogonal to the rotor axis and showing two variants in which several circumferential grooves are provided on the rotor guide;
- Figs. 6 and 7 are views similar to Figs. 1 and 2, relevant to an embodiment in which the circumferential groove is formed on the rotor;

  Fig. 8 is a view similar to Fig. 6, showing the position of the rotor during a discharge phase;
- Fig. 9 is a view similar to Fig, 7, relevant to a variant in which the rotor has a pair of grooves like those shown in Fig. 5; and
- Fig. 10 is a view similar to Fig, 2, relevant to an embodiment in which the circumferential groove is formed by the intersection of the rotor and the rotor guide.

Description of Preferred Embodiments

Referring to Figs. 1 to 3, a vacuum pump 1 comprises a rotor 2, for instance a rotor with a single vane 8, as disclosed for instance in WO 2009/046810 and FR 2640699. An end portion 2A (support portion) of the rotor is concentrically mounted in a guide 3 formed in the pump body. The opposite portion 2B, in which vane 8 is arranged, eccentrically rotates in a chamber 9 in which an intake duct (not shown) and a discharge duct 10 open. A driving joint 4, transmitting the rotation of a drive shaft (for instance the shaft of a vehicle engine) to rotor 2, is fastened to portion 2A. Reference symbol A denotes the axis of rotation of rotor 2.

Such a pump structure and its general operation are wholly conventional and they do not need a more detailed description.

Guide 3 has formed therein a supply channel 5 for a lubricant, typically the engine oil, intended also to create a seal between the inside 1A and the outside 1B of the pump. Channel 5 ends into a circumferential groove 6 that, in such an embodiment, is formed in guide 3 and lies in a plane perpendicular to the axis of rotor 2. Contrary to the prior art, according to the invention groove 6 does not extend over the whole circumference of guide 3, but only over an arc extending between the two points 6A. There is therefore a region of guide 3 where groove 6 is interrupted.

Groove 6 is to be interrupted where it is necessary or important to provide the hydrodynamic bearing opposing the pressures arising during the discharge phases of the pump (two at each revolution, in the case of the rotor shown in Fig. 3). As stated before, such pressures apply to rotor 2 forces, the resultant of which is shown by arrow RF Figs. 1 and 3, which push the rotor against guide 3 in the region opposite discharge duct 10. This is the angular region where the hydrodynamic bearing has to be maintained. Such a region has an extension varying depending on the application and indicatively ranging from 60° to 180°.

The extension of groove 6 will be therefore a trade off between the two opposite requirements of not excessively interfering with the formation of the hydrodynamic bearing, and of still having an effective barrier against air leak from the outside. Tests performed by the Applicant have shown that a satisfactory trade off is obtained with an angular extension of groove 6 ranging from about 150° to about 300°. Values at present considered as preferable are in range of about 180° to 220°.

Once the requirement of having the hydrodynamic bearing in the region opposite discharge duct 10 has been met, there are no particular constraints about the position of groove 6. By way of example, Fig. 1 shows an asymmetrical groove 6, one branch of which extends as far as to a point diametrically opposite the end of channel 5. In the alternative, however, groove 6 could symmetrically extend at both sides of channel 5: such a solution would allow a better pressure distribution between both groove branches.

Groove 6 can have any cross-sectional shape (rectangular, trapezoidal, arc of circumference, etc.).

An axial groove 7, extending from circumferential groove 6 towards the inside of the pump or, preferably, extending at both sides of circumferential groove 6, as shown in Fig. 2, is provided at the outlet of channel 5 into circumferential groove 6. Multiple axial grooves 7, distributed along circumferential groove 6, could also be provided.

The invention solves the problems mentioned above. Indeed, since the circumferential groove does not extend over the whole circumference of the rotor and/or of the guide, an increase of the useful contact area between the rotor and the guide occurs, and the negative phenomenon of the break of the hydrodynamic bearing is avoided. In turn, this entails:

- a reduction of the wear at the end of the operating life of the rotor guide and the rotor;
- a better stability of the pump performance between the beginning and the end of the operating life; and
- a better stability of the oil flow absorbed by the pump between the beginning and the end of the operating life.

In the variant shown in Figs. 4 and 5, multiple circumferential grooves, for instance two grooves, are provided in the rotor guide.

In Fig. 4, grooves 16', 16" still consist of arcs of circumference arranged in a plane orthogonal to the rotor axis and they are axially spaced apart along guide 13. Supply channel 15 ends into one of such grooves, for instance groove 16', whereas groove 16" (and the other grooves, if any) will receive oil from groove 16' through one or more axial grooves 17.

In Fig. 5, grooves 26', 26" are inclined relative to the rotor axis. More particularly, grooves 26', 26" are substantially tangent to each other at the end of supply channel 25 and diverge towards their ends 26'A, 26"A, with either a rectilinear or (as shown in the Figure) a curvilinear behaviour. Like in Fig. 4, channel 25 ends for instance into groove 26', whereas groove 26" (and the other grooves, if any) will be supplied with oil through one or more axial grooves 27. The solution shown in Fig. 5 is suitable for a counterclockwise rotation of the rotor (arrow F1). Indeed oil, after having lubricated guide 23, tends to remain trapped by the V-shaped junction formed by grooves 26', 26", and hence it is not dispersed out of guide 23, thereby further improving the lubrication. Beyond the end of channel 25, grooves 26', 26" may continue as separate grooves or join into a single groove.

Figs. 6 to 8 show a pump 101 where the circumferential groove is formed in support portion 102A of rotor 102. The example shown still refers to a pump with a single vane rotor, as shown in Fig. 3, hence to a pump having two discharge phases at each rotor revolution. In such a situation, the circumferential groove consists of two arcs 106-1, 106-2, symmetrical with respect to rotation axis A of the rotor and hence two interruptions are provided in the groove. The values given above for the angular extension of the groove refer in this case to the overall extension of both arcs 106-1, 106-2. Both arcs 106-1, 106-2 are formed in such a way that, at each discharge phase, one of the interruptions is located in the region where the resultant RF of the forces due to the discharge acts, as shown in Fig. 8. In the example illustrated, oil supply cannel 105 directly ends into rotor 102 and supplies both arcs 106-1, 106-2 through a diametrical channel 115 internal to the rotor.

If the pump has a number of discharge phases different from two at each revolution of rotor 102, the circumferential groove formed on the rotor will include an arc and an interruption for each discharge phase, and the arcs and the interruptions will be so arranged that one interruption passes in the region opposite the discharge region at each discharge phase,.

In the variant shown in Fig. 9, a pump 121 is shown where each arc 125 formed in support portion 122A of rotor 122 is branched, beyond internal supply channel 115, into a pair of inclined grooves 126', 126" similar to grooves 26', 26" shown in Fig. 5. As it is obvious for the skilled in the art, in order oil is collected at the vertex of the V-shaped junction, the latter is oriented in opposite direction with respect to the situation shown in Fig. 5, that is, it opens in the rotation direction, here again assumed to be the counterclockwise direction.

Lastly, Fig. 10 shows a pump 201 in which circumferential groove 206 is formed between facing surfaces of steps 212, 213 in the side surface of support portion 202A of rotor 202 and in the side surface of guide 203, similarly to what is disclosed in WO 2009/046810. Of course, according to the invention, step 213 will be formed only over a portion of the guide circumference.

Of course, a plurality of circumferential grooves may be provided also in the embodiment of Fig. 10.

It is clear that the above description has been given only by way of non-limiting example and that changes and modifications are possible without departing from the scope of the invention as defined in the appended claims.

In particular, even if a pump with a vane rotor has been referred to, the invention can be applied also to other types of rotary vacuum pumps. Moreover, is it is self-evident that the invention can be applied whatever to rotation direction of the rotor may be.

Patent claims

1. Rotary vacuum pump, which comprises a rotor (2; 102; 122; 202) mounted for concentric rotation in a rotor guide (3; 13; 23; 103; 203) and in which at least one circumferential groove (6; 16', 16"; 26', 26"; 106-1, 106-2; 206) is provided between facing side surfaces of the rotor (2; 102; 122; 202) and the guide (3; 13; 23; 103; 203) for receiving a lubricating and sealing fluid, said at least one circumferential groove (6; 16', 16"; 26', 26"; 106-1, 106-2; 126, 126', 126"; 206) including at least one arc having an angular extension of less than 360°,

<u>characterised in that</u> said at least one circumferential groove:

- has at least one interruption arranged to enable creating a hydrodynamic fluid bearing in a region opposite a discharge region of the pump (1; 101; 121; 201), over a whole axial extension of said side surfaces;
- is formed in the side surface of the rotor (2; 102; 122; 202) or in the side surface of the rotor guide (3; 13; 23; 103; 203) or is defined by steps (212, 213) of said side surfaces; and
- includes one arc (106-1, 106-2; 126) and one interruption for each discharge phase of the pump, the arcs and the interruptions being so arranged that each interruption passes in a region opposite a discharge region of the pump (101; 121) during a discharge phase.

2. The pump as claimed in claim 1, wherein the at least one circumferential groove (6; 16', 16"; 26', 26"; 106-1, 106-2; 126, 126', 126"; 206) has an angular extension ranging from about 150° to about 300°, and preferably from about 180° to about 220°.

3. The pump as claimed in claim 1 or 2, wherein the at least one circumferential groove (6; 16', 16"; 26', 26"; 106-1, 106-2; 126, 126', 126"; 206) is in communication with at least one axial groove (7; 17; 27) for conveying the lubricating and sealing fluid towards the inner side (1A) of the pump.

4. The pump as claimed in any preceding claim, wherein the at least one circumferential groove (6; 16', 16"; 26', 26"; 106-1, 106-2; 126, 126', 126"; 206) extends on a surface perpendicular to a rotation axis (A) of the rotor or on a surface inclined with respect to said axis.

5. The pump as claimed in any of claims 1 to 4, comprising a fluid supply duct (105) ending into the rotor (102) and communicating with the arcs (106-1, 106-2; 126) through at least one channel (115) formed inside the rotor (102).

6. The pump as claimed in any of claims 1 to 5, comprising a circumferential

groove which branches, or where each arc (126) branches, at a fluid supply zone and forms a substantially V-shaped end section (26'; 26"; 126', 126").

7. The pump as claimed in any of claims 1 to 5, wherein a plurality of circumferential grooves (16', 16"; 26', 26") are provided, which are distributed along an axial direction of the rotor and the guide.

8. A method of lubricating a rotary vacuum pump (1; 101; 121; 201), in which a lubricating and sealing fluid is introduced between facing side surfaces of a pump rotor (2; 102; 122; 202) and of a rotor guide (3; 13; 23; 103; 203) in which the same rotor concentrically rotates, and at least one circumferential barrier sealing against air leaks between external and internal pump sides (1B, 1A) is formed by means of such a fluid, said circumferential sealing barrier being obtained by providing, in the side surface of the rotor (2; 102; 122; 202) or in the side surface of the rotor guide (3; 13; 23; 103; 203) or in steps (212, 213) of said side surfaces, at least one circumferential groove having an angular extension of less than 360° and including at least one interruption arranged to enable creating a hydrodynamic fluid bearing in a region opposite a discharge region of the pump (1; 101; 121; 201),

characterised in that said at least one circumferential sealing groove includes one arc (106-1, 106-2; 126) and one interruption for each discharge phase of the pump, the arcs and the interruptions being so arranged that each interruption passes in a region opposite a discharge region of the pump (101; 121) during a discharge phase.

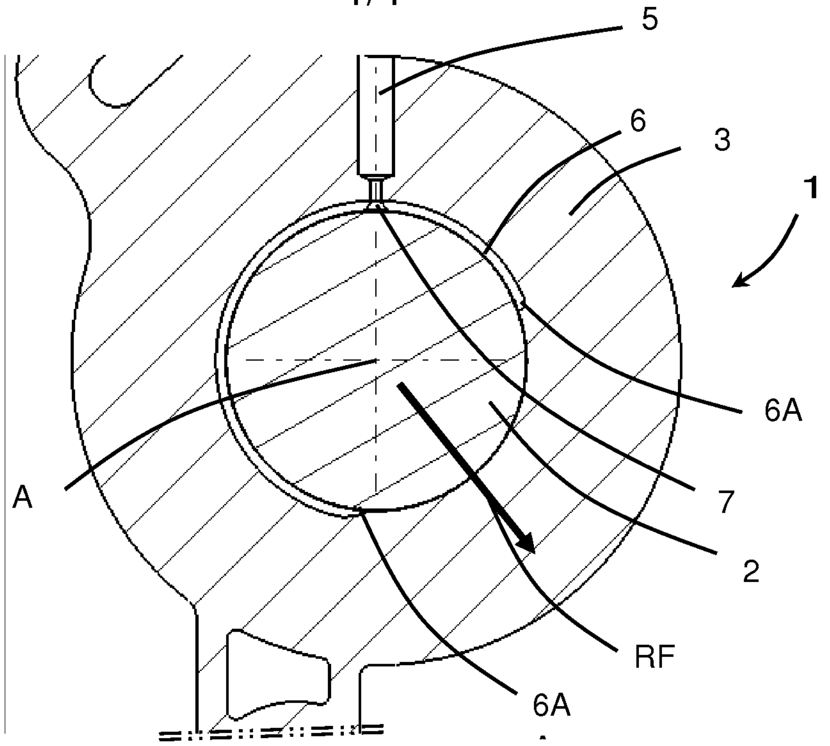

FIG. 1

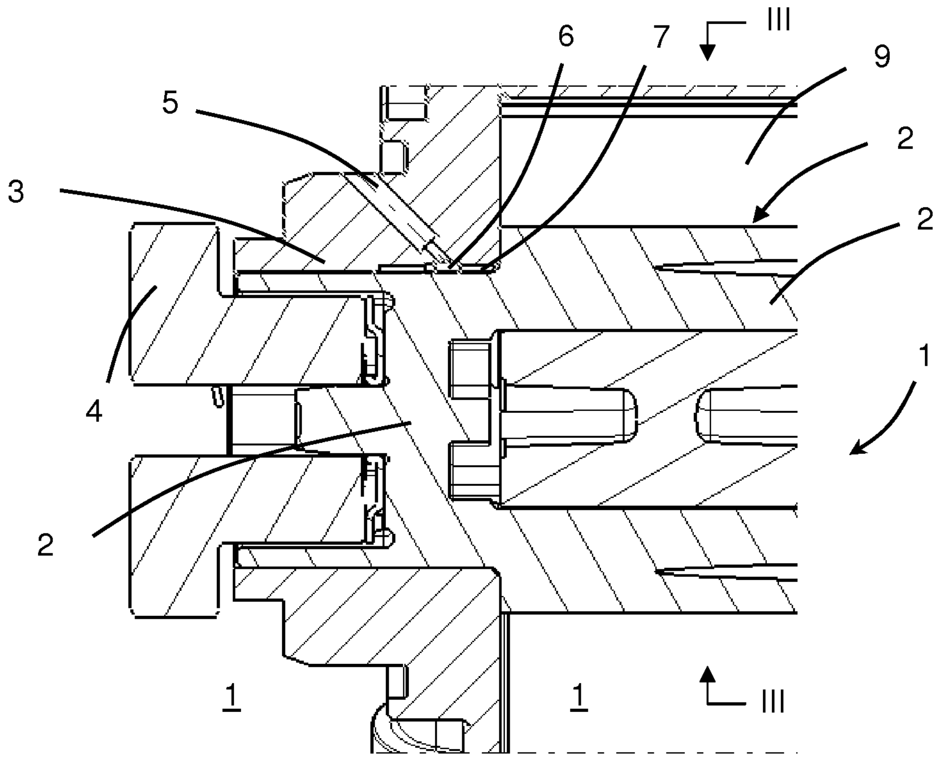

FIG. 2

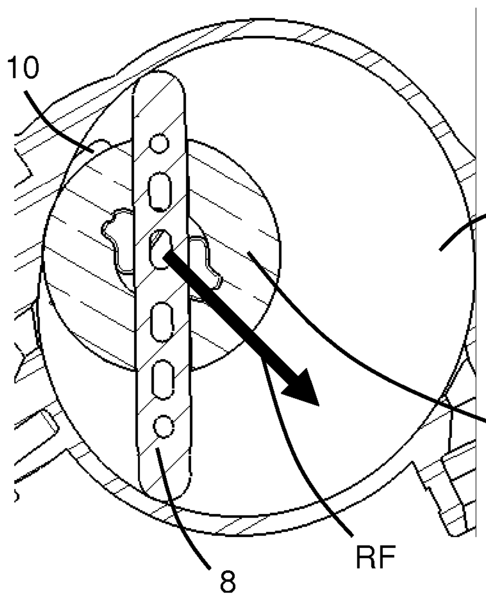

FIG. 3

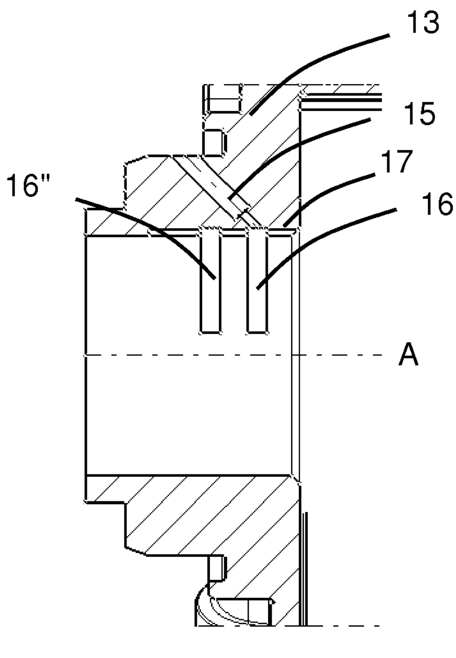

FIG. 4

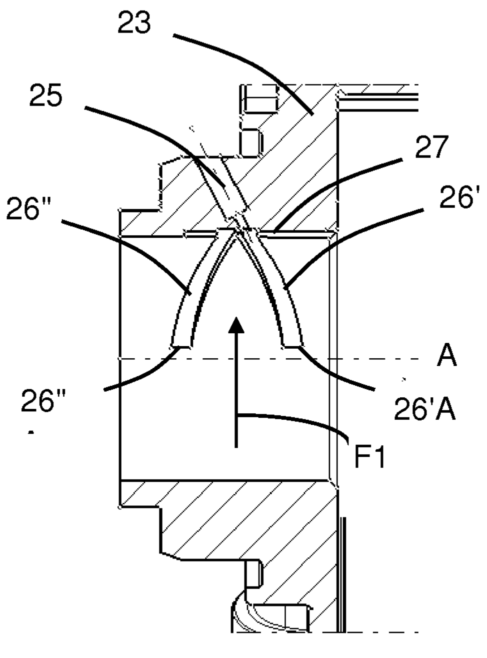

FIG. 5

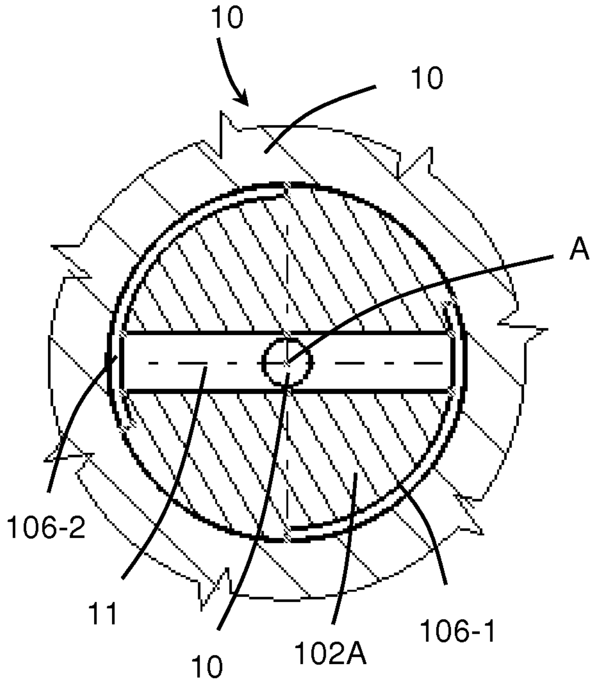

FIG. 6

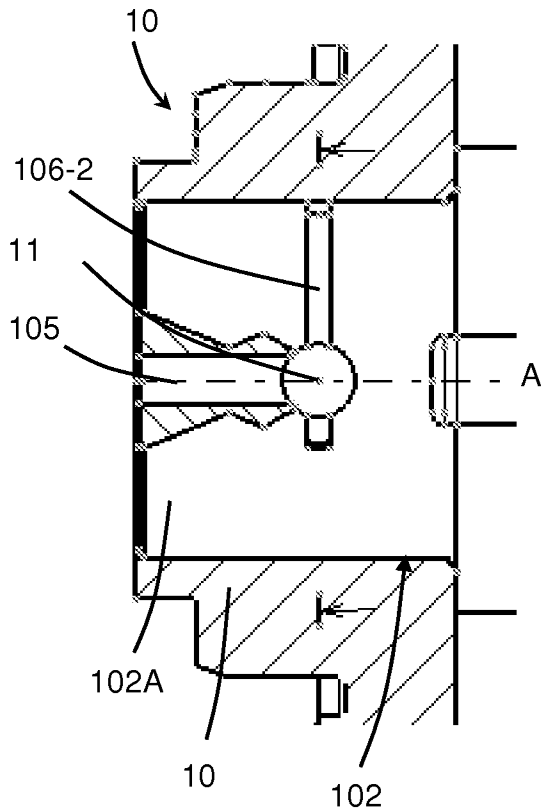

FIG. 7

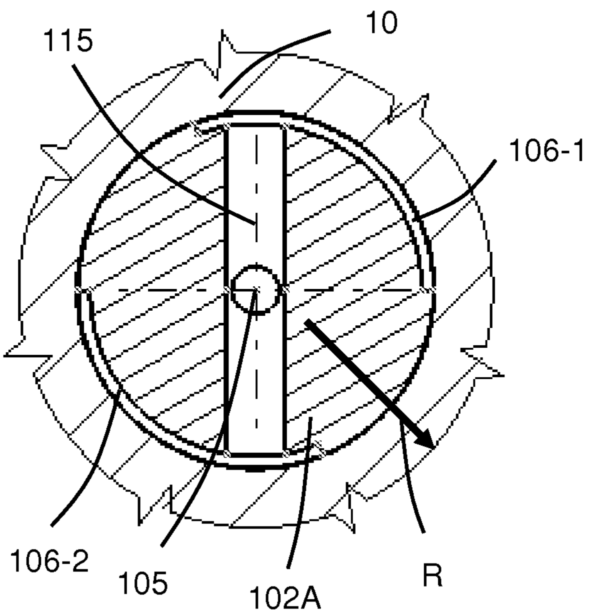

FIG. 8

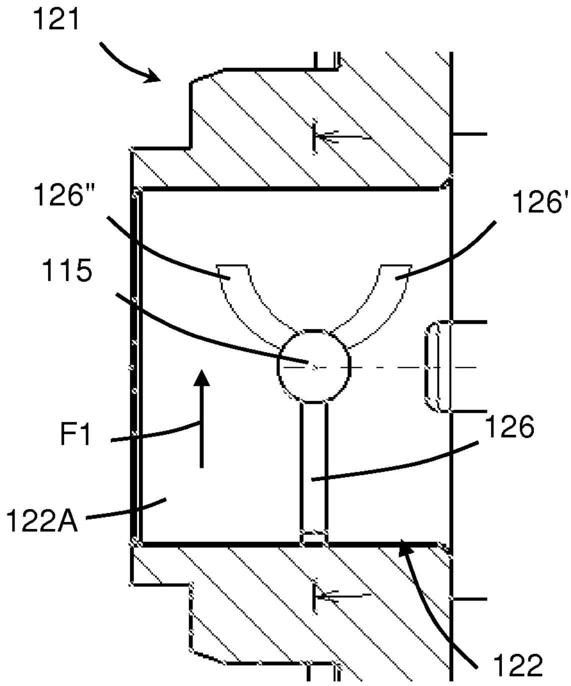

FIG. 9

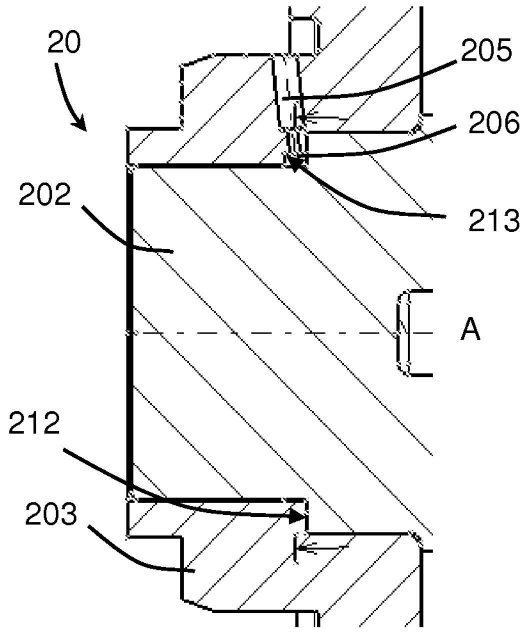

FIG. 10